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ABSTRACT

For this paper, prepared as an input to an ongoing assessment called "Adult Literacy and the New Technologies: Tools for a Lifetime," the literature on the use of technology in educational programs was reviewed, and the use and instructional effectiveness of audio equipment, television, computers, and interactive media were examined. Special attention was paid to the cost-effectiveness of educational technology and its use in adult literacy programs. The main findings of the review were as follows: (1) technology now makes possible many things that could not be accomplished by teachers or texts alone, increases student motivation, and enables special needs students (such as students with disabilities and non-English speakers) to achieve success in educational activities that they might otherwise fail or not be offered; (2) the current state of technology development does not encourage acquisition of and application for learning; (3) the effectiveness of technology depends on the context of its application and the quality of the technology materials available for learners; and (4) because no one technology can do everything any more than one teaching study can be appropriate to all students, subjects, and circumstances, educational technology is most effective when used in that specific combination with other technologies and instructional approaches that promises to be most effective for a particular purpose or goal. (Contains 70 references.) (MN)

Learning from Technologies: A Perspective on the Research Literature

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by
Saul Rockman

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Contents

If we accept that education is not something abstract and disconnected from the realities of life, then it follows that to be of any use, it should not only help people to know and to understand, but to do.

Anne Jones

The task is simply too big for accustomed ways and traditional procedures in education.

Nell Eurich

Learning from Technologies: A Perspective on the Research Literature

After looking at numerous summaries of research on technology, and many individual studies of the application of assorted technologies to meet the instructional needs of various audiences, certain conclusions seem clear. Educators, technophiles and the general public may take solace in the notion that students of all kinds can learn almost all things by using electronic technologies in appropriate ways. But the technology is not the critical issue; what is done with the technology is more important than what the technology is.

As Clark (1983, 1989) has been saying for years, the technology — be it audio, video or computer — is just a medium for something to be delivered. In and of itself, it is essentially benign, providing some benefits, and absorbing resources at a significant rate; instructional methods make the difference. Kozma (1991) does not fully agree, but his arguments focus on the perceptual characteristics and attributes of the technology, while minimizing the contextual issues of its use. The evidence I have seen supports Clark's contention. Educators have learned to use technology to attract, to motivate, to instruct, and to change attitudes and beliefs. Individuals have also used technology to learn, to create, to organize, and to share. Among these consequences are the elements of formal and informal learning for students of all ages and characteristics.

Let me begin with the caveat that any review of research in this area is constrained, since most of what is available in the literature is based on studies conducted in schools and colleges, studies that take an experimental approach, and studies that look at short term outcomes and often modest treatments. This is a limitation of the educational research culture. Research conducted on the application of technology in education has been criticized for a number of other reasons, too (Becker, 1987; Krendl & Lieberman 1988; Rockman 1992), so that results must be approached with some tentativeness.

I have evaluated a collection of research studies indicating that students can learn knowledge and useful skills using a variety of technologies. Krendl and Lieberman (1988), Roblyer and others (1988), the Office of Technology Assessment, (U.S. Congress 1988, 1989), Johnston (1987), Hasselbring (1984), Thompson et al., (1992), Fletcher (1990) and others have reviewed, analyzed, and assessed large numbers of research studies about the effects of technology on learning and have arrived at similar conclusions. Yes, people do learn using various technologies. But they also report that how well they learn from these technologies (and often whether they learn at all) is influenced by factors extrinsic to the technology. The context of its use has dramatic consequences for the impact of technology.

Research on broader aspects of learning that incorporate technology, and studies of adult out-of-school populations are more difficult to find. Research on formal instruction for adult audiences is also difficult to locate. Most studies on these audiences are program evaluations that lack the research rigor and, consequently, generalizability. Nevertheless, the collection of research — overall — consistently points to common conclusions.

There is a growing body of new research that extends, in innovative ways, how technology is used successfully by students in formal educational settings. As educators — and researchers in cognition and technology — move towards tackling real-world problems in the classroom, towards working in cooperative and collaborative groups, and provide adult technology tools for younger

students, the role of the teacher and the student — and even the classroom and the school building — change. Some few schools have become places where students accomplish meaningful tasks in a self-directed fashion, assisted by appropriate technologies. These changes are certainly not widespread, nor at this time of limited resources, are they likely to be for many years.

New research efforts on cognition and learning, such as intentional learning (Scardamalia et al. 1989), anchored instruction (Cognition and Technology Group, 1990), Denis Newman's Earth Lab (1990), and Salomon's intellectual partnerships (Salomon et al., 1991), while focusing on using computers, are really efforts to understand how to design learning environments that will influence how students learn. They begin to explore the distinction between effects *with* technology and effects *of* technology (Salomon, 1991).

Contemporary technology is more powerful and software tools and simulations more capable of providing meaningful assistance to students and workers. Technology now makes possible many things that couldn't be done by teachers or texts alone. Moreover, technology increases student motivation and makes it possible for those along the edges of traditional education — those with disabilities or non-English speakers — to accomplish educational activities that they might otherwise fail or not be offered.

However, most schools do not have access to the newer technologies nor to the software needed for powerful applications; most teachers are not trained to take advantage of what is now possible. And much of the available research on the implementation of technology is weak, misguided, or deals with trivial issues (Krendl and Lieberman, 1988; Rockman, 1990b, 1992).

Just as it is clear that students can learn with technology, it is also clear that no one technology can do everything, any more than one teaching style can be appropriate to all students, all subjects, and all circumstances. The solution for teaching and learning is to select a combination of methods, a mix of

technologies and instructional approaches that promises to be most effective for a particular purpose or goal.

In addition, just as the approaches to research have been changing, the technology itself has also been evolving and mutating. Studies done on new technologies of ten, or five, or even three years ago may be outdated, the technological capabilities replaced by newer technologies currently going into educational settings. As a result, it is difficult to assign characteristics to one technology. For example, television as it is widely viewed from broadcasts and videotape is a mix of auditory and visual images portrayed in a linear fashion. But contemporary technology makes it possible for a viewer to gain random access to video images using a videodisc player and a barcode reader or a computer. Digitized video can appear on computer screens, providing moving images that can be embedded in a text document. This fluid interchange among media and technologies makes it difficult to ascribe a particular attribute to a specific medium. Television may have audio and visual information, but its application defines it more than does a mere listing of television's evolving attributes.

In the sections below, I review some of what is known about the effects of various technologies on teaching and learning: audio, television, computer, and multimedia. The empirical results must be seen in light of the technologies available at the time of the research; different approaches might be used today to explore the same set of questions. I also explore some of the applications of technology in adult learning settings, especially for literacy development, and the cost-effectiveness of newer technologies. I conclude with a perspective on how and why technology can be useful for learning and what might be necessary to ensure its successful application.

Audio

Over the past three decades, audio has been the most widely available technology, yet the one on which the least amount of research has been conducted. It is pervasive in our society — available in car or on street corner — and yet it is barely in our consciousness. Audio technology itself has progressed dramatically in terms of quality, accessibility, size, and variety. Now it includes radio, telephone, audio tapes, compact discs, and even computers. Nevertheless, much of what has been learned has come from studies conducted in the thirties, forties, and fifties.

Audio, especially radio, has been used for education since the 1930s. As a separate medium, audio found significant use in the 1950s and 1960s in two ways. Radio courses, such as the New York School of the Air, provided instruction during the teacher shortages of the early baby boom years. Audiotape in language labs came into vogue with the availability of resources from Title III of ESEA that supported the development and acquisition of educational materials. Over the intervening years, the greater appeal of newer technologies, such as television and the computer, diminished the interest of technophiles and educators in audio, except as an attribute of other technologies. In OTA's (1988) report on the use of technology for teaching and learning, *Power On!*, audio was not mentioned except as a component of other technologies. At a time when radio is still a highly viable commercial medium, when audio books are selling millions of copies to commuters, when the music business is stronger than ever, audio still has little visibility in education. This is especially unfortunate given its cost effectiveness. Only in developing countries, does one find radio used for the central instructional function.

Audio, as a stand alone medium, has its limitations, especially in a culture driven by television. It does not generate the motivation nor sustain the interest that can be garnered by more visual media. Video jukeboxes and MTV are testimony to the desire to add video to music. At the same time, talking head television is denigrated by most viewers as unappealing and of little value. Yet,

in contrast to the mass audience of the highly visual evening news, all-news channels, C-SPAN, and public television's MacNeil-Lehrer provide counterpoint with an essentially audio program.

The educational value of audio, in its varied forms, has been substantiated over the years, especially in comparisons of face-to-face instruction with audiotapes and radio. These research studies indicate little if any difference in achievement outcomes or student motivation. In most subjects and with students of all ages, radio and audiotape versions of courses presented orally by live instructors have proven to provide equivalent or superior instruction (Thompson et al., 1992). When one approach has proven superior, gains have been attributed to learner motivation or instructional approach (Wilkinson, 1980). For courses in language learning or music appreciation— subjects in which the audio channel is stressed and multiple channels of information are not needed — these audio media have benefits that appear on cognitive outcome measures (see, for example, Hill and Gasser, 1977).

Students can learn effectively from audio as a stand alone instructional medium, but as with other technologies, listening skills must be taught and developed. And as will be noted for other technologies, there is some evidence that lower-achieving students, both children and adults, benefit more from stand-alone audio materials than do better performing students (Bates, 1983; Hayter, 1974). These learner attributes have been attributed to increased motivation associated with the use of technology, novelty effects on achievement and attitudinal outcomes, and lack of distractions (and greater concentration on task) with this medium.

The telephone has been an audio-based instructional device used successfully with students of all ages since the 1950s (Johnston, 1987). It has two primary uses: reaching hospitalized or home-bound students, and providing specialized expertise to classrooms or learners at a distance. While little research had been done on this particular application of technology for learning, the evidence suggests increased motivation and equivalent learning when compared

to face-to-face instruction, and the availability of experts in the classroom that would otherwise have never been available. These are outcomes associated with the context of use, rather than the technology.

Nevertheless, audio has proven to be a successful and cost-effective approach to instruction for certain audiences and for certain kinds of content. This is especially true for students who have difficulty understanding written arguments and those who need to regularly repeat the information to be learned, such as in language learning where audio provides feedback and repeats stimulus materials to emulate. Johnston (1987) reports an analysis from The Open University that identifies the "appropriate uses" of audio including: access to primary resource material that is oral in nature; condensed arguments from texts provided by lecturers; greater attitude change through dramatic readings and focused arguments; flexibility for the instructors who are not tied to a particular time and location; and as a means of providing structure for the learner who must listen to regular broadcasts or hear tapes of finite length.

Audio has some other uses in education, in addition to transmitting lectures or instructional materials to homebound students. Thompson et al. (1992) note research indicating that background music can facilitate audio instruction and background music can increase the effectiveness and efficiency of the instructional process in special education. Music, as part of relaxation exercises, has also been shown to have positive effects on learning.

Speech compression (increasing speaking speed while maintaining the speaker's pitch on audiotape, cassette, or disk) is also a useful technology for learning, especially valuable if the learner can control the rate of speech compression. Conclusions from Thompson et al. (1992) suggest that the use of rate-controlled speech compression tape recorders can enhance the achievement levels of both high and low aptitude students on aurally presented material. The rate of compression students choose is related to familiarity with the subject matter, level of difficulty, and knowledge of the language of instruction.

At this point, it is worth noting the distinction between audio for stand-

alone instruction, and audio as part of a more comprehensive medium, such as television. For instance, background music may be an important factor in understanding much of what is in film and video. It can enhance understanding of content, provide audio cues for action, and set mood; sound effects define action and its consequences. The audio channel is much more capable of capturing attention if it is used as an interjection on the visual channel, rather than being continuously parallel with the video. If the message is being carried in the visual, then the audio doesn't have to repeat it all, rather it can accentuate the central idea or point out critical features for student learning. Research on children's television programs have identified ways of using audio cues that help viewers attend to the important content issues of the program and improve comprehension (Anderson and Collins, 1988). Music, voice quality and gender, and sound effects can all contribute to improving learning.

Television:

Television is pervasive in our society, providing information, entertainment, and instruction. It has been affecting our knowledge and learning in ways we neither recognize nor acknowledge (Postman, 1979), especially in informal learning, where the context of viewing does not provide accountability for the implicit curriculum. Social norms and expectations are developed from extensive viewing; belief systems are established (Huston et al., 1992). Yet, only in structured settings does any mediation of viewing influence what is being learned. And while television gets blamed for many of society's problems, including lower achievement test scores and children who don't read, television viewing out-of-school does not appear to influence in school achievement directly (Roberts and Rockman, 1987).

Nevertheless, television has been an instrument of education since its early days, as have most technologies. It has grown in magnitude, quality, and reach, from providing inservice instruction and college courses during the baby boom era of teacher and classroom shortages, to the early childhood efforts of Sesame Street, to instructional television programs for elementary and secondary classes, to distance learning efforts, such as Star Schools (US Congress, 1989).

For adult learners, one can point to the success of informal distance learning, especially the use of public broadcasting for adult education, and of cable channels that provide extensive informal learning opportunities. Much of this television use is for self-growth, informed by experience and directed by the motivated individual — from learning how to cook to remodeling a house. Some structured applications trickle over into formal education with tens of thousands of adults enrolled in GED programs and many thousands more in college courses. PBS distributed college telecourses enroll over 250,000 students in more than 1,800 colleges and universities each year. And in more than 35 states, stations broadcast Kentucky Educational Television's GED television programs to an appreciative audience. Kentucky reports that 75 percent of those that took the course passed the test (APTS, 1990).

The research on television and learning can be divided into research on the characteristics of televised presentations that lead to learning (such as pacing, on-screen images, audio cues, etc.) and the broader impact of televised instruction on achievement and motivation. That is, research on television production and research on television's impact.

The former, often called critical features analysis, is based on large amounts of research and evaluation, much of it conducted on Sesame Street, The Electric Company, and other children's educational and instructional productions. This work has created a body of knowledge about production techniques and their relationship to attention, comprehension, and learning. The resulting knowledge has gone into the creation of newer television series that have instructional intent and it has informed a generation of television producers about the value of thoughtful planning and program design. Much of this work focuses on elements in the visual and auditory components that maintain or increase attention, a necessary but not sufficient condition for learning from mediated instruction (Anderson and Collins, 1988).

The body of research built upon these evaluation studies is useful for television production, but it also has implications for cognitive learning. Video provides a set of transient symbol systems (in contrast to books or still images) that create opportunities for processing information (Kozma, 1991). Viewers at all ages do not sit zombie-like in front of the screen; they interact with it perceptually and cognitively. Visual attention changes in a curvilinear fashion associated with age, from very low levels during infancy to a maximum during the late elementary years, declining somewhat during adulthood (Anderson and Field, 1983). Moment-to-moment attention might wander, but "viewers" constantly monitor the presentation at some superficial level and can be called back by audio cues and will sustain viewing with strong action or continuing visual effects. Anderson and Collins (1988) provide an extensive review of the literature on the formal features of television programs that influence children's learning, cognition, and attention. Much of what they identify as critical

attributes of television for children's learning can be applied to adult learning settings, as well. Efforts in health education (Mielke and Swinehart, 1976), in advertising (Schwartz, 1973), and in training (Jolliffe, 1990) have transferred ideas developed from formative evaluation of children's television programs to an adult audience. Research on the formal features of television programs has helped identify effective production techniques for commercials as well as for prosocial television programs (Huston, et al. 1992).

> ...it has been established, unequivocally and irrevocably, that a well-designed and produced television program can and does teach. This is especially verifiable when the potentials of the medium ~~are~~ exploited and content visualization is maximized. It is most especially true in the hands of a skilled teacher. (Cambre, 1987)

The second kind of research has demonstrated that, as Cambre asserts, good television, used well, can produce good learning. There have been numerous examples of successful television programs in formal educational settings, efforts that have resulted in improved knowledge and achievement, more positive attitudes, and increased motivation (Johnston, 1987; Cambre, 1987). Research has looked at outcomes in school and at home, with audiences from preschool children to college students. From increased ability to read (The Electric Company) to increased reading (Reading Rainbow), from thinking skills (ThinkAbout) and science (3,2,1! Contact!) to economics (Trade Offs), students have been changed as a result of watching a television series under the direction of an interested and informed teacher.

Moreover, it matters little to the outcomes of viewing how the video image is received by the viewer. It can be by broadcast signal, cable, videotape, videodisc, or satellite; what matters is why and how the materials are used. While certain kinds of transmission systems have attributes that affect implementation (such as the search capabilities of videodisc or the stop-and-start functions of the videotape player), it is that effort to use video, not the technology, that determines the effectiveness of the instruction and the quality of

the learning (Clark, 1983); Thompson, et al. 1992). The importance of audience and context (for whom and under what conditions the video is to be used) are the determinants of impact.

For young children and school-age viewers — audiences on which most of the research has been conducted — the fundamental conditions that make television effective for learning are:

- attentive viewing (thus the efforts to identify and apply formal features to gain and hold attention),
- adult mediation (providing a social context for learning, giving encouragement to view and an explanation of content when needed),
- post-viewing review or rehearsal of desired responses, and social support (an opportunity for learners to construct their own knowledge of the content domain, respond to the ideas of others, and obtain feedback about their perceptions, beliefs, performance, and knowledge).

These contextual factors have been shown to improve learning in settings using various technologies for instruction, not just television. These factors of learning from media combine a variety of theories and philosophies of how learning best takes place, including both behavioral and cognitive constructivist approaches. They provide insight into how to use technology, not which technology to use.

Issues of the viewing context influencing what is learned from television is clarified further in a study by Krendl and Watkins (1983). They asked fifth-graders to view a fifteen-minute educational video; half the students were told to watch for entertainment purposes and the other half was to watch for educational reasons (and told that they would be tested on its content). While there was no difference in the students' recall of the storyline, those who viewed with an instructional purpose understood the content at a greater depth and could make more inferences about the meaning of the show.

Adult learners, like their younger colleagues, are influenced by the context in which they view television programs. As Johnston (1987) notes about Britain's

Open University, "Students are very pragmatic learners. Their use of the television and radio programs depends greatly on whether they believed that they would be tested on the material. If early tests or study-guide questions suggested the shows were not integral to achievement, students would watch the programs less often."

In addition to formal educational efforts, television appears to be an especially potent medium for conveying information about health and nutrition, especially for reaching poorly educated people (Huston, et al. 1992; Pearl, et al., 1982). Purposeful, but not directly instructional television has been used in social education campaigns from the sixties on, and the research stresses the influence of contextual issues on the success of health-related efforts. Ettema, Brown, and Luepker (1983) found that an information campaign about cardiovascular health increased viewers' knowledge and decreased the knowledge gap between individuals of higher and lower socioeconomic status. An informational television series from CTW helped create awareness of health issues, increased knowledge, and led to some behavioral efforts to improve and safeguard health (Response Analysis, 1976). Television was also more effective than other media in an Australian campaign about disabled persons. It was most effective for creating awareness about disabilities, but less effective for changing attitudes and behavior (Gething, 1984, cited in Huston, et al. 1992).

Fundamentally, the research evidence is that television can indeed teach, but the contextual factors lead to more or less successful efforts. We know much about the elements that improve attention and capture the interest of viewers, but the context of viewing — the purpose, support, and adjunct materials — contribute more to the eventual success of the instructional effort. Television alone, without the surround that makes it powerful, does not have the effects that warrant its use for instruction and learning. Alone it can create awareness and often motivate, but it does not teach well. How we choose to use television is more important to its impact than how the program was designed and for what purpose it was originally created.

Computers

In the past decade, discussions of technology in education (and in public policy) have most often referred to the computer, to the exclusion of other technologies used for learning. Microcomputers have been infused in schools with great rapidity, more than a sixty-fold increase over ten years — from 50,000 to more than 3 million, and it is increasingly found in homes, especially those having family incomes over $40,000. Suburban schools and suburban homes are likely places to find computers.

Computer technology is changing rapidly. Thus, expectations of how computers are to be used for learning and teaching, and studies stretching the ability of computers to provide learning opportunities to students of all kinds, makes much of what we have learned less important than what we can learn about how to use new technologies for important educational goals.

As with previous technologies, much of the early research conducted on computers tended to be comparisons with other kinds of instruction. Researchers focused on the computer as the independent variable, and assumed that the computer itself was somehow affecting the learning process. For the most part, these studies have shown that students using computers learn just as well, if not better than students in more traditional settings (Hasselbring, 1984; Krendl and Lieberman, 1988; Roblyer, Castine, and King, 1988). That is, when comparing traditional in-class instruction with computer-based instruction, there are some positive effects favoring the technology, although most studies demonstrate little, if any, statistically significant and meaningful differences.

Just as with other technologies, the computer when used effectively and appropriately, can produce learning and change attitudes among a wide community of learners. And like other technologies — but even more so for computers — there has been great expectation about the potency of this technology to create learning environments that would substantively change the classroom from what it is today. Proponents have proffered increased individualization, greater learner control over the instructional process, more

powerful simulations, the ability to manipulate complex variables, and skill and knowledge development in a non-punitive environment as attributes of this technology that would affect learning and teaching. All of these are possible, yet few have been widely demonstrated and shown to be dramatically effective and affordable for all kinds of students. The computer can be misused as easily as it can be powerfully applied.

Computers have been as widely studied as any technology to date, but the complexities and capabilities of computer technology have resulted in a modest accumulation of outcomes that substantiate learning impact. Of all the technologies other than print, the computers is the one that permits individualization at a reasonable cost. Thus, more research evidence is available about the attributes of the audience and the context in using computers than about other media for learning. At the same time, a great deal of the research conducted on the application of this technology to education falls prey to the same "technohype" that its proponents have offered. There is little evidence that the use of technology, itself, has an impact. How it is used, and with what software capabilities, is more important than the fact of using the computer.

As a by-product of its perceived utility, as with other "new" technologies, much research is weak, poorly conceived, and rests on enormous expectations from trivial treatments (Clark, 1989; Rockman, 1990b). Treatments of 15-minutes a week or a total of two or three hours over a school semester are thought to influence standardized test scores. Realistically, efforts to enhance skills and improve knowledge must rest on more than the promise of a technology to influence education; it must rely on conceptual understandings of instruction and implementation strategies that develop a context for learning with technology.

Academic effectiveness:

Looking first at the data on effectiveness, the available overviews point directly to the capacity of students to learn with computers. In their research

synthesis, Roblyer, Castine, and King (1988), report that, contrary to many of the earlier research overviews, computer technology has a greater success with college students and adults than with elementary and secondary students. The greatest effects noted in the research studies are found in the application of computers in science instruction; science simulations appeared to have the most impact. In contrast, drill-and-practice materials in mathematics, often noted as relatively effective in earlier research syntheses, did not demonstrate as powerful effects in Roblyer, Castine, and King's analysis.

Fletcher's (1992) synthesis of effectiveness data also indicates powerful outcomes with computers, relative to traditional kinds of instruction. Compared with a teacher in front of a classroom, computer-based instruction improved students' knowledge and skills at all educational levels. The average effects size (a standardized measure of effects, the closer to 1.0 the better) aggregated from a large set of studies ranged from .47 for elementary school research to .40 for secondary, to .26 for college, and .42 for adult education. These indicators speak to a real and substantial improvement when students were provided with computer-based learning opportunities. Fletcher's data contradict Roblyer, Castine, and King, and are more consistent with earlier research on effects size (e.g., Niemiec et al. 1987).

While consistent reports of effectiveness indicate a powerful educational treatment is possible with computers, how the technology is applied is a basic determiner of the kinds of results that will be obtained. Becker's review of computer-based integrated learning systems (a network of computers providing a comprehensive curriculum in selected subjects incorporating an extensive assessment and reporting system) indicates that consistent findings from different sites using the same set of technology and learning materials was, in fact, unusual, and that implementation was more important than either the technology or the software (Becker, 1991a). The role of the teacher contributes greatly to the kinds of effectiveness outcomes obtained, even using the same materials (Levin, Leitner, and Meister 1986).

Attitudes:

Research on attitudes and motivation in relation to technology-based instruction is fairly limited, though many of the published conclusions seem to be positive. Research has looked at the changes in attitudes towards the subject area, towards computers, towards schooling in general, and towards users themselves (Roblyer, Castine, and King, 1988; Krendl and Lieberman, 1988). Students do not appear to be particularly intimidated by computer-based instruction, and, in fact, enjoy it at least in the short term. For some, especially poor achievers, and urban, inner city students, access to the computer may be a high point in the day, where a neutral, non-punitive opportunity is available (Becker, 1991b). They show the greatest positive change in attitudes (Roblyer, Castine, and King, 1988).

Some of the positive outcomes associated with computers may be novelty effects of using technology rather than the instructional potential of the delivery system itself (Clark, 1983; Krendl and Lieberman, 1988; Rockman, 1992). Novelty effects — people tend to enjoy new and different activities when they are first introduced, but that their level of enjoyment tends to diminish over time — have not been studied as a part of many technology research efforts, often because of the academic preference for short-term, small-scale experimental applications of technology .

Student ability and SES:

While most studies of the impact of technology have focused on instructional effectiveness and attitude change, research has also explored the role of specific student characteristics and classroom factors that influence impact. Becker (1991b) examined the relationship between student ability and access to technology and found that by the time students reached middle school, ability level was a significant predictor of the types of computer opportunities students would experience. Higher ability students were much more likely to have greater access to computer technology and more freedom to explore their

interests in programming instruction, problem-solving tasks, and word processing applications, in contrast to drill-and-practice software. This outcome is also associated with socioeconomic status; students in urban, inner city schools, regardless of ability level, are provided with different computer applications — and different instructional materials of all kinds — than their suburban peers (Rockman, 1992).

In other research overviews that have discussed student ability level (Hasselbring, 1984; Niemiec et al. 1987; and Roblyer, Castine, and King, 1988), there is a consistent finding of stronger positive effects in computer applications, especially drill-and-practice programs, with low-ability students and younger students. However, low-ability students are rarely given access to computers for applications other than remediation, and positive effects may be attributable to the novelty of using a computer rather than filling in workbooks with similar content (Becker, 1991b). Furthermore, low-ability students may profit comparatively more from such instruction; high-ability students may find it boring and may already score high enough on achievement tests to show little gain regardless of treatment.

Role of the teacher:

After reviewing ten years of research on computers, Collis (1989) notes that there is an abundance of evidence that the teacher is a critical variable in the impact of any educational tool. Central to the use of technology in education is the inevitable impact of the teacher's "intellectual agenda" on computer effectiveness. This consideration "vehemently contradict[s] the popular notion that computer-based lessons can be self-implementing . . . teachers need a clear understanding of the purposes of computer materials, and an image of how to manage teaching in a new way, and a detailed map of the subject matter they have to teach" (ETC, 1988, p.20). And even in a cost-effectiveness study, Levin, Leitner, and Meister (1986) found "profound" differences in the impact of very structured, computer-delivered drill-and-practice when it was monitored by

different teachers, even though the integrated learning system was designed to be virtually teacher-independent.

Pogrow (1990) concludes that, after years of research in developing student thinking skills by using computer software as the basis for intensive student-teacher interactions, it takes extensive amounts of time to produce improvements in student performance. Moreover, most higher-order learning occurs from the student-teacher dialogues rather than from the use of the software, similar to teacher interventions for television programs. Pogrow reports that more learning occurs from sophisticated dialogues around the use of simple software, than from the use of sophisticated software.

The new constructivism:

This research on the role of the teacher provides an early insight into how research on computers and learning has been changing. Considerations of the effectiveness of computers for learning has moved from Piaget towards Vygotsky, with greater emphasis now on the importance of social interaction in cognitive development and the need for learning to be in context (Salomon, 1992; Polin, 1992). Salomon (Salomon et al., 1991) offers a distinction between effects *with* technology in contrast to effects *of* technology. The effects of a technology that is an "intellectual partner" for sustained change in cognition and later performance, not merely improvement in immediate performance. The different perspective on learning from computers ". . . changes the question from "is there a cognitive effect of technology?" to "Can a cognitive effect of technology be engineered by designing the technology, the activity, and the setting to foster mindful abstraction of thinking skills and strategies." We move from looking at computers — or any technology — as an independent variable in the learning equation, to learning how to use the technology to create a learning environment that will encourage, assist, and enhance student learning. This distinction dramatically changes the focus of research from the computer and what it does to the design and implementation of the lesson.

For instance, Riel (1991, 1985) has documented positive effects on students' reading and writing skills using computer networks to communicate with one another. She argues that combining "writing for a purpose" with "writing to a particular audience" provides a meaningful and compelling context for student writers. Using the technology to create a functional learning environment, Riel notes both improved motivation and improved skills. Writing appears to be much more effectively learned when students direct their writing to specified audiences to accomplish goals rather than spending years 'practicing' writing in school (Daiute, 1985).

Salomon, in his 1992 American Educational Research Association address, notes that the previously separate functions of design, implementation, and research have become linked in recent cognitively-based technology projects. Scardamalia's intentional learning environments or Newman's networked environment take a more comprehensive view of how learning takes place and identifies the role of computers quite differently than earlier studies of effectiveness. Newman (1992, 1990), for instance, describes a school's computer network that can change the organization arrangements within a school, modify the instructional patterns, and influence social relationships among students. In Earth Lab, the entire inner city school environment, not just the technology, becomes part of the research focus; students collaborate on science projects, and benefit from the lack the barriers across subject areas. Classroom tasks extend beyond a single period or even a school day, and use databases, desktop publishing, and other "adult" tools in their self-directed instructional efforts.

Salomon (1990) also recognized the need to incorporate the technology in a social and instructional context, so it was not technology but a school ecology that he studied. To make effective use of computers under real classroom conditions, the researcher had to change most aspects of classroom teaching and learning "from a didactic mode of instruction to exploratory activities, from individual learning to cooperative learning teams, from passively rehearsing the Constitutional clauses to rewriting them, from being tested to formulating

speeches during the 'Convention,' and from acquiring computer literacy in a sterile 'computer literacy' class to using the computer as a practical daily tool."

In these studies, and others, a new kind of constructivism is appearing, one that incorporates interdisciplinary, authentic, and active learning and that appropriates computers and other technologies to accomplish self-defined, meaningful work. Powerful technology tools are emerging, and are unfortunately not widely available, nor are many teachers prepared to use them even if they were. These tools let students and teachers create a new learning environment that permit them to develop new thinking skills and learning strategies. Local area computer networks permit students and teachers to share information and exchange ideas easily; on-line databases extend the resources of the school a thousand times over, providing enormous amounts of information to learners who must develop strategies for capturing and synthesizing the data; fluid interrelationships among digital data of all kinds, including video, bring information together in innovative ways, and permit learners to organize and present their knowledge to others.

It is now possible to develop technology supported instructional environments that provide engaging learning tasks, and a social context for learning, with knowledgeable adults giving encouragement and direction when needed, and learners to constructing their own knowledge of the content domain, responding to the ideas of others, and obtaining feedback about their perceptions, beliefs, performance, and knowledge. To make these environments widely available would take enormous resources and time; barriers, such as teacher training and remodeling older classrooms, make it even less likely. Nevertheless, looking at evolutionary changes is more positive than expecting no changes at all. These newer approaches to teaching and learning will gradually find their way into classrooms, and technology will certainly be part of them. For without the technology facilitating the change, these new approaches to learning would not be possible.

With this perspective, the concerns of earlier researchers on the impact of technology on the individual seems misplaced. These newer studies can be contrasted with those that ask if the introduction of computers will increase test scores and those that explore the direct influence of computers without consideration of the context of instruction. Given the variety and range of learners, and the diversity of contexts in which they operate, it appears difficult to lay down a rule about the characteristics of learners that should be taken into account for the development of electronically mediated materials for instruction. Rather, the new cognitive research explores learning and thinking within a context that can be defined and augmented by the technologies available to learners. The technology serves as a trigger and a tool; the learning environment changes and so do the participants in the instructional events. Some classroom events now become possible (or even probable) and, by using technology to do the things we want to do and couldn't otherwise do, it becomes our intellectual partner. As the technologies evolve and extend our reach to be learners and teachers, they must change the questions we ask of them, moving away from looking at the impact of technology to the intelligent application of technology as part of an instructional setting.

Interactive Multimedia

There is little research on multimedia when compared to work on computers and video for learning. Multimedia, as a widely available learning system, has had a short life, and much of the research work has been exploratory and descriptive, designed to help create more effective and appealing products, rather than assess the impact of interactive multimedia products on learning and attitude change. Nevertheless, to a modest degree in education, and more in business and industry, in the military, and in the health professions, research on the use of multimedia has demonstrated some significant learning outcomes.

While electronic technologies seem to be merging as more and more information becomes digital — and many believe that soon everyone will have multimedia on their desktop — most of what has been studied is fundamentally computer-controlled, random-access, video materials. Multimedia can bring together audio, video, text, graphics, and still pictures under the control of a computer, potentially bringing the best of each to the instructional task. More fluid and integrated approaches, such as moving video illustrations of text, are not yet widespread. Computer-based instructional materials with access to videodisc illustrations or video-based instruction with computer-managed, navigable pathways through the materials are the most common approaches in education and training.

Multimedia combines technology attributes that are robust in their own right; it has the potential to aggregate the impacts of the individual constituent parts. By adding controllable video, learners are given great power over an intensive experience, which allows them to conceive of alternatives that would not otherwise be available (Kozma, 1991). Further, this video context for computer-driven instruction strengthens student interest in the cognitive issues and focuses the experience more effectively (Cognition and Technology Group, 1990). Effectively created multimedia instruction can provide its own context or environment for learning. By creating realistic simulations and even a cyberspace representation of a large database (Henderson, 1992), students can feel

as if they are participants in a war theater or that they can manipulate information in novel ways. These are new approaches, only beginning to be studied in well-conceptualized ways, and not fully part of the research base for applying technology to instructional tasks. Multimedia instruction, at this level, is experimental and not widely available. It tends to be extraordinarily expensive and found only in the military or in health fields.

In the context of education and training, three elements seem to be clearly supported by the research evidence available to date (Apple, 1989; Fletcher, 1990). First, achievement on cognitive instruction using multimedia technology is as good or better than that provided by traditional instruction. In the familiar comparison of a new technology with traditional classroom instruction, multimedia often proves more effective in raising achievement levels (Bosco and Wagner, 1988; Branch, et al., 1987). Students learn as much or more using the technology, although novelty effects could easily contribute to the effectiveness of multimedia instruction.

Second, the use of multimedia for cognitive and skills instruction is an efficient method of teaching (Bunderson, et al., 1984; Branch, et al., 1987; Peterson, Hofmeister, and Lubke, 1988). Improvements in efficiency range from twenty to over forty percent, suggesting significant improvements in productivity available from the technology (Fletcher, 1992). Reasons for both effectiveness and efficiency include students spending more instructional time-on-task, greater motivation in using the technology, and greater efforts in instructional design to create better instruction.

Third, student attitudes towards learning and towards technology use are improved following experience with multimedia (Bunderson, et al., 1984; Peterson, Hofmeister, and Lubke, 1988). In most studies on the application of multimedia for instruction, students consistently prefer the technology-based ›proach to the more traditional classroom instruction, and they recommend it to others. They also identify other content areas in which they see multimedia as potentially useful applications (Bosco and Wagner, 1988).

There are other incidental advantages reported from the existing research. These include: the use of multimedia technology provides additional time for individual instruction and follow-up; student production efforts enhance independence, self-concept, and motivation; and the interactive nature of the experience appears to enhance retention. Even elementary school students are able to manage the various pieces of equipment and learn the manipulable features of interactive multimedia in a short time. They also illustrated great variability in individualizing the multimedia experience they chose.

In his review of multimedia instruction in higher education, in industry, and in the military, Fletcher (1990) notes that in comparison to conventional instruction, interactive multimedia is more effective. The average effects size (a standardized measure of effects, the closer to 1.0 the better) ranged from .69 for higher education studies, to .51 for industry, and .39 for the military. Moreover, he notes that the more that the interactive features of the medium were used, the more effective the resulting instruction.

The value and potential of interactive multimedia seems well-received by business and the military, organizations that have a great need for specific skill development, in diverse locations, and for large numbers of motivated learners. Education is slower to take up the technology, based mainly on the cost of designing and producing the instructional materials and the need for training teachers to use it effectively. Moreover, interactive multimedia has the great potential to dramatically shift the relationship between teacher and student. By placing the responsibility for learning more on the student and changing the role of the teacher from the center of the instructional experience, interactive multimedia provides great counterpoint to today's schools and other formal educational experiences.

The expectations brought to the instructional event are different, as well. Learners are quickly aware of the powerful tools in their hands, and learn to manipulate the technology components to achieve desirable ends (Ambron and Hooper, 1990). By having the ability to choose their own paths through the

information, to organize it in unique ways, and to gain a sense of their own control over the computer and video materials, students are empowered to take responsibility for their efforts and their learning. Design issues are critical to the success of these instructional materials, and the accompanying costs are still significant for education.

Conceptually, interactive multimedia instruction is a powerful and still developing technology. However, widespread investment is a risky proposition for traditional education, given the changing nature of the technology and its costs. The effectiveness of this technology has been demonstrated, but the attributes that lead to its potency have not been well defined (Ambron and Hooper, 1990; Fletcher, 1990). As risk capital is applied to develop new instructional resources, a body of useful materials can lead to wider adoption by education. Further, as business and industry, the health professions, and the military develop instructional resources that can be transferred and adapted by schools and colleges, the technology will be adopted with greater alacrity.

At the same time as the investment in software is increasing, the cost of the technology needed to implement interactive multimedia is dramatically falling. At some point the two lines will cross — desirable instructional materials and affordable technologies — and the widespread adoption of multimedia for learning will occur.

Cost-Effectiveness

Cost-effectiveness is a difficult construct for educational research, especially for studies assessing traditional education, with its broad goals and its variable outcome standards. Without acceptable outcomes and standards, educational researchers cannot gather reliable and valid data that meet the statistical assumptions of cost-effectiveness models (Far West Laboratory, 1992).

Political and status reasons also influence the cost-effectiveness concerns for educators in elementary and secondary education. Slavin (1991) looked at 21 studies of IBM's computer-based Writing-to-Read program in Kindergarten and first grade and concluded that there are text-based programs available through the National Diffusion Network (NDN) that are more effective in accomplishing the same goals and for 100 times less cost. 0Nevertheless, adoption of Writing-to-Read continues, motivated by top down decisions by state- and district-level administrators who find secondary benefits in large-scale technology efforts.

In contrast, for specific skill development or training in business and industry, in the military, and in the health professions, the educational impact and cost-effectiveness of technology — especially interactive computer and multimedia instruction — is widely accepted and proven.

In a meta-analysis examining the data from 100 studies on flight simulators, maintenance training simulators, and computer-based instruction Orlansky (cited in Gerber, 1990) concluded that all three are as effective and more cost efficient than using the traditional alternatives: training in real aircraft, practice with real maintenance equipment, or classroom training. While there was no doubt the technology-based approaches saved considerable time and operating costs, the conclusions weren't as clear about the transfer of training from the instruction setting to the job itself.

Most large corporations that make substantial investment in technology-based training conduct their own studies to figure out whether a new technology is as effective as the training it replaced. Much of that information is not widely available. But of the evidence that is available, certain attributes consistently

emerge: more people can be trained at less cost (the equipment can be used at all hours), with less travel to a central site for companies with far-flung offices, students have more time-on-task which leads to higher retention of information, and instructors commonly note greater worker motivation (Malcolm, S.E., 1992; Rosenberg, 1990).

However, new technology solutions for training are costly. It may take 300 hours to produce one hour of computer-based training, in contrast to 30 hours of development for one hour of classroom instruction. But authoring programs are making it easier and cheaper for new productions and, at the same time, commercially available products are raising the level of expectation for program quality. Dexter Fletcher (1992, 1990) in reviews of interactive courseware noted substantial effects size for both computer-based and interactive videodisc instruction. His analysis of a collection of studies finds about a 30% time savings for computer-based instruction and interactive videodisc courses, with interactive videodisc more cost effective than other approaches. "There is evidence that in many settings and for many subject matters, interactive courseware (ICW) programs are more effective and less costly than more conventional approaches to instruction, but conclusive evidence on the cost-effectiveness of ICW programs remains to be established (1992, p.22)."

While Fletcher's conclusions lead him to endorse interactive videodisc instruction as effective and less costly than conventional instruction for the military, the increase in productivity he identifies may not be transferable to other sectors that have less invested in training programs or who have less clearly defined goals for their educational efforts.

With the exception of radio/audio education (where cost-effectiveness concepts and measurement techniques may not have been available to the researchers of former decades), television, computers and interactive videodisc have all been shown to be as effective or better than traditional face-to-face instruction, and to be cost-effective for some learning activities and for some audiences. It is a question of under what conditions each technology should be

applied and when the cost of one technology is more appropriate to a particular end. Effectiveness and relative costs of technology-based instruction have been most often studied in comparison to what it was replacing — face-to-face instruction. Rarely have studies compared learning and cost effectiveness between equivalent efforts on computers and on television, or using interactive videodisc. Fletcher concludes that interactive video is most effective based on average effects size of a set of independent studies, not a direct comparison.

Common sense plays a part, as well. For a national literacy program in a developing country, radio supplemented by text may be more cost-effective than any alternative. But for second language learning in higher education, interactive video, regardless of its cost, may be more cost-effective than a language lab, because of the value added by the visuals and the potentially greater amount of interactivity, as well as the possibility of spreading the cost over many students in many colleges. Cost-effectiveness is not only an outcome issue in the domain of learning, it is a design and marketplace problem for those who have to create and distribute the instructional materials and technologies. In an environment of unlimited resources, almost everyone could learn well from interactive videodisc simulations.

Adult learners:

Common sense also argues that computer technology is certainly not essential in the teaching of adult literacy skills; much of the adult population in the U.S. became literate before the advent of computer and other contemporary technologies. Research indicates that computer technology alone is insufficient to effectively develop basic literacy in either children or adults. While integrated learning systems (ILSs) come closest in this attempt, even their proponents argue that literacy does not develop in the absence of social interaction.

The body of research on adult literacy and technology is scant; much of the information we have is the result of program evaluations, efforts to assess the impact and value of various approaches to literacy development. These evaluation studies rarely meet the criteria for valid and reliable research; they do not contain data comparing the effectiveness of the various technologies used, nor provide comparisons to traditional instructional methods. And while the vast majority of these project reports indicate successful outcomes, the goals of the evaluations were often to ensure further funding rather than add to the body of knowledge. However, they do reveal a great deal of information about the role and impact of technology.

For adult learners not in formal educational programs certain facts are already established: adults learn literacy and other basic skills most effectively in conjunction with their jobs or in a functional context, and they retain the abilities if they are put to use immediately.

The military demonstrated this approach most effectively in Project 100,000, in which large numbers of marginally literate youths, who would have otherwise failed entrance screening were taken into the military (Eurich, 1990). When instruction in the basic skills was combined with technical training for the recruits' assigned military jobs, training was effective.

In a comparative study supported by the Education Department's Office of Vocational and Adult Education, workplace literacy programs were delivered by videotape, individual tutoring, and computer-assisted instruction (International

Masonry Institute, 1990). Participants liked the videotaped instruction because they could be trained at home on their own schedule; it supported their work and recreational schedules and reflected both personal responsibilities and mood. However, the participants wanted to watch the tapes with another person, pairs that would allow for mutual social support but would not cause personal embarrassment. They also suggested that group tutoring would be more effective than individual tutoring, and that the computer-assisted instruction was the least successful, with participants continuing to express a fear of the technology and finding the initial software unsuitable for adults (later more appropriate software was located with better results).

From studies in the military and in adult learning settings, it is clear that adults must be taught as adults in suitable surroundings, not as older children in the schoolroom. Instructional materials must be at the appropriate level, suggesting that adaptations of children's software are not as useful as more appropriate efforts using tools such as word processing.

The Army also developed JSEP, the Job Skills Education Program, that tests soldiers in basic competencies needed for the most common jobs, and then it provides remediation in those skills in which a soldier is deficient. All tests and all of the tutorials are delivered by computer, although some lessons are paper-and-pencil exercises. The computer tracks individual progress and produces cumulative data on all users. Progress can be monitored, and staff can identify slackers; assessment is also more easily accomplished. JSEP is not intended to teach an illiterate person to read and write, nor does it provide job training. But trainees, for example, improve their reading and mathematical skills for use in working through a tank repair manual.

Although evaluations of JSEP thus far are inconclusive, and the Army has not expanded the program greatly, an adapted version is being tested in a technical school in White Plains, New York. The results of this effort are not yet sufficiently explored to know whether this transfer of technology is working.

Among non-military efforts that find consistent and reliable results, and that

reflect the issues in the new cognitive approaches to learning with technology, is a literacy project in St. Paul. It incorporates computer-based instruction and individual tutorials, and uses software from different ILS vendors to provide the comprehensiveness and variety needed by the learners (Turner and Stockdill, 1987). Results showed substantial gains in reading and mathematics skills as a result of applying the technology to instruction. Researchers concluded that "the effectiveness of the program and its use of technology depends on the competent and committed staff. Computers and effective staff are mutually reinforcing, each extending and increasing the effectiveness of the other." Other factors in the successful program include both what the availability of the technology permits, such as individualization (time allocations, pacing and content), having the learners work on topics of interest and importance to them, and non-instructional issues, such as an adult environment (in a mall, not a school), convenience, and the respect of staff for students.

Adult learning is most successful when it draws on the individual's previous experience, is related to immediate needs and involves the adult in decision-making about instruction (Eurich, 1990). It is necessary to say, however, that a mix of technologies and a mix of instructional approaches — all under the direction of a teacher or a valid diagnostic program — may provide the rich environment in which adult students can best learn. The use of the computer is of special importance: technologies must be used to instruct the larger number of people who require the education, both at the workplace and outside of it.

A last word:

The difficulty of using technology effectively is based on the changes it is likely to make in the way we provide education. As more capabilities are available — multimedia, access to enormous information resources, connections with experts and peers throughout the world — how we use those capabilities over time changes the nature of our educational institutions. Technology bumps up against the culture of traditional educational institutions as it take more central roles in assisting and providing instruction. It is a threat, upsetting the nature of teaching. Institutions fear that they might easily invest in obsolescence, that they have to retrain teachers, and that technology may have no real purpose in learning — it can be done just as well with people.

If technology in adult learning settings — or even in colleges and universities — continues to be anything like the use of technology in elementary and secondary schools, it will only have a modest impact. Working on the edges of the central activities of the schools, inadequately conceptualized and poorly implemented, and not well understood by the instructors — technology has not been able to have the impact that its proponents hoped for. Nor has it had the opportunity to influence education in any significant way. While television has been able to attract students to adult learning settings, the technology used for adults in these settings has not lived up to the promises. It has been, and continues to be, an add-on to the instructional program. Learning is something that a student does under the direction of a teacher. This notion has not changed in hundreds of years.

In order for something to be substantively different in our formal and informal learning settings, some preconditions have to be met. First it (the technology) has to be accessible (enough terminals, available when people want them), with appropriate software (designed for adults, clearly related to areas of student interest and appeal, and immediately applicable on the job, at home, or in interactions in the real world). If technology holds out the promise for learning any subject, at any time, and in any location, we have a far way to go. Researchers are certainly exploring new avenues for technology to be useful, but

the efforts are limited by resources, ingenuity, and still emerging concepts of how technology can best be used. Furthermore, there is a lag time between the emerging concepts and their widespread availability for learners.

For the wealthy, or the elite, or the person with a high risk/high outcome job, the expensive technologies may fall into place. But for the rest of the population, especially the forgotten adults and children in our cities and rural areas, the expectation is that the poor get computers for drill-and-practice on basic skills, while the rich get teachers and the opportunity to do independent work and learn higher-order thinking skills on their computers, at home and in school. Unfortunately, the poor are getting computer education that does not reflect what we know is central to effective learning with technology.

Moreover, the current state of technology development does not encourage acquisition and application for learning. Computers are not ready for easy application to formal and informal education settings. Several of the adult learning programs whose research we have noted use multiple integrated learning systems because no one of them provides all of the necessary materials in an organized fashion and in a way that works with large numbers of students. Different learning styles, different learning needs, different initial capabilities, all set up barriers to simple technology solutions. Standardization may be needed for widespread adoption of computer and multimedia instructional materials — except for specific job skill development where economies of scale may permit unique solutions. At present, there are too many choices among hardware and software for intensive investment by the public sector in long-lasting solutions using limited resources. However, that shouldn't keep people from trying new solutions involving technology. Only by playing out diverse possibilities can we learn more about how to apply technology intelligently so that learners can benefit from it.

The effectiveness of technology depends on the context of its application and the quality of the technology materials available for learners. What we have not yet established is what would happen if electronic technology were permitted to

redesign formal and informal learning environments to exploit their full potential. While there are alternative viewpoints on what this might look like (Dede, 1990; Perelman, 1992; Rockman, 1991a), there are few focused efforts in business or in the public sector to achieve the dramatic change that would be expected. The Whittle Edison Project, the NASDC venture, and other efforts to change the structures of formal K-12 education, also have the potential to change how we approach education at the postsecondary level, and for lifelong learning as well.

In business, electronic performance support systems, make possible just-in-time training for information-age workers (Gery, 1991). These systems are collections of computer-based materials, including information, software productivity tools, reference materials, guidance and coaching aimed at improving learning. These systems can produce rapid proficiency through simulations and guided practice on exercises that take into account the job context. Just-in-time training tells how to do something at the moment employees need to learn it so that they can immediately go back and apply the learning. When employees have trouble performing certain tasks, the just-in-time training might provide a simulation to teach the concepts, some step-by-step examples for practice, and an opportunity to apply the new knowledge when ready. When the need to learn more arises, employees might need some reference assistance. The performance support system provides online referrals to people or materials with information, collegial support, or new opportunities for personal growth. Employees can be in touch with a network of colleagues and experts who can inform and direct their work.

Whether a system of this kind is practical in the near future for education depends greatly on the kinds of curriculum we want to provide our students. Performance support systems are certainly expensive. Corporations, while they find them powerful, are moving slowly to develop them. Much of what we currently do in school focuses on memorization and management rather than on practical performance. But as new curricular ideas become more prevalent,

technologies can rise to the challenge of providing meaningful and motivating instruction that does improve performance in context.

Whether this future gets driven by the public or private formal education institutions or by the demands of the workplace for quality, flexibility, skills, and autonomy is still to be determined.

Much of the potential for contemporary technologies — computer, multimedia, performance support systems — and of the network technologies that make them even more powerful, awaits a focus on education and lifelong learning as important for our society. At conferences that discuss policy issues about technology for learning, the most frequently heard expression is *opportunity*. Opportunity is more than a potential. As our society faces severe pressures — economic, social, educational — opportunity and the need for action press for new policies and new activities. Technologies of various kinds have become central to our economy and to our way of life; people can accept their roles as catalyst, facilitator, and as an extension of our senses. These policy elements seek multiple settings for actions and demand participation by both public and private sector actors. Pressures for change encourage our persistence and can result in meaningful applications of technology for learning.

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